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MECHANICS.

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198. Proposed by J. SCHEFFER, A. M., Hagerstown, Md.

Three spheres of the same material, radii R, r, S, rest upon a horizontal plane, touching each other. Find the radius of a sphere of the same material as the others which, being placed upon the other three spheres, will just prevent the latter from separating, the coefficient of friction between the spheres being μ, and between the spheres and the table being μ'

Solution by G. B. M. ZERR, A. M., Ph. D., Parsons, W. Va.

Let x=radius of top sphere center Q, R=radius of bottom sphere center P. The forces acting on the sphere radius R are its own weight W, the friction F, the friction F', and the normal reaction between the two spheres R. Let nW_1 be the part of the weight of the sphere radius x supported by the sphere radius R. $\angle DPC=\beta$.

Now $FHC=RDC$. $F=R\left(\dfrac{DC}{HC}\right)=R\tan\frac{1}{2}\beta$. $\therefore F=\mu R$ or $\mu=\tan\frac{1}{2}\beta$.

$$F'=\mu'[W+nW_1]=R\sin\beta-F\cos\beta=R(\sin\beta-\tan\tfrac{1}{2}\beta\cos\beta]=R\tan\tfrac{1}{2}\beta.$$

$$\therefore R=\frac{\mu'[W+nW_1]}{\tan\frac{1}{2}\beta}=\frac{\mu'}{\mu}[W+nW_1].$$

Resolving vertically, $nW_1=R\cos\beta+F\sin\beta$.

$$\therefore nW_1=R[\cos\beta+\tan\tfrac{1}{2}\beta\sin\beta]=R.\quad \therefore nW_1=\frac{\mu'}{\mu}[W+nW_1].$$

Let δ=density of each sphere. $\therefore W=\delta g\times\frac{4}{3}\pi R^3$, $W_1=\delta g\times\frac{4}{3}\pi x^3$.

$$\therefore nx^3=\frac{\mu'}{\mu}[R^3+nx^3].\quad \therefore n=\frac{\mu' R^3}{[\mu-\mu']x^3}.$$

Let mW_1 be the part of the upper sphere supported by sphere radius r, and pW_1 the part supported by sphere radius S. Then

$$m=\frac{\mu' r^3}{[\mu-\mu']x^3},\quad p=\frac{\mu' S^3}{[\mu-\mu']x^3}.$$

But $n+m+p=1$.

$$\therefore \frac{\mu'[R^3+r^3+S^3]}{\mu-\mu'}=x^3,\text{ and }\therefore x=\sqrt[3]{\frac{\mu'[R^3+r^3+S^3]}{\mu-\mu'}}.$$

199. Proposed by G. B. M. ZERR, A. M., Ph. D., Parsons, W. Va.

A sphere of water, radius $\frac{1}{49}$, the earth's radius, is brought together by mutual attractions of particles from a state of infinite diffusion. Find its temperature owing to the amount of work done by these forces.